EARTHQUAKE VULNERABILITY ANALYSIS FOR LOCAL GOVERNMENTS

Bay Area Regional Earthquake Preparedness Project
A Project of the Governor's Office of Emergency Services

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September, 1989

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Some of the information in this guide was derived from a draft manual by Terence P. Haney for the Southern California Earthquake Preparedness Project: *Manual of Procedures for Performing an Earthquake Vulnerability Analysis,* July, 1984.

INTRODUCTION

The Vulnerability Question

How vulnerable is your community to damage from an earthquake? Every community in California should know the areas in which damages are possible in order to prepare for, and reduce losses in a major earthquake. An earthquake vulnerability analysis is a first step in dealing with the reality of the earthquake threat in California, and should be part of every community's disaster plan.

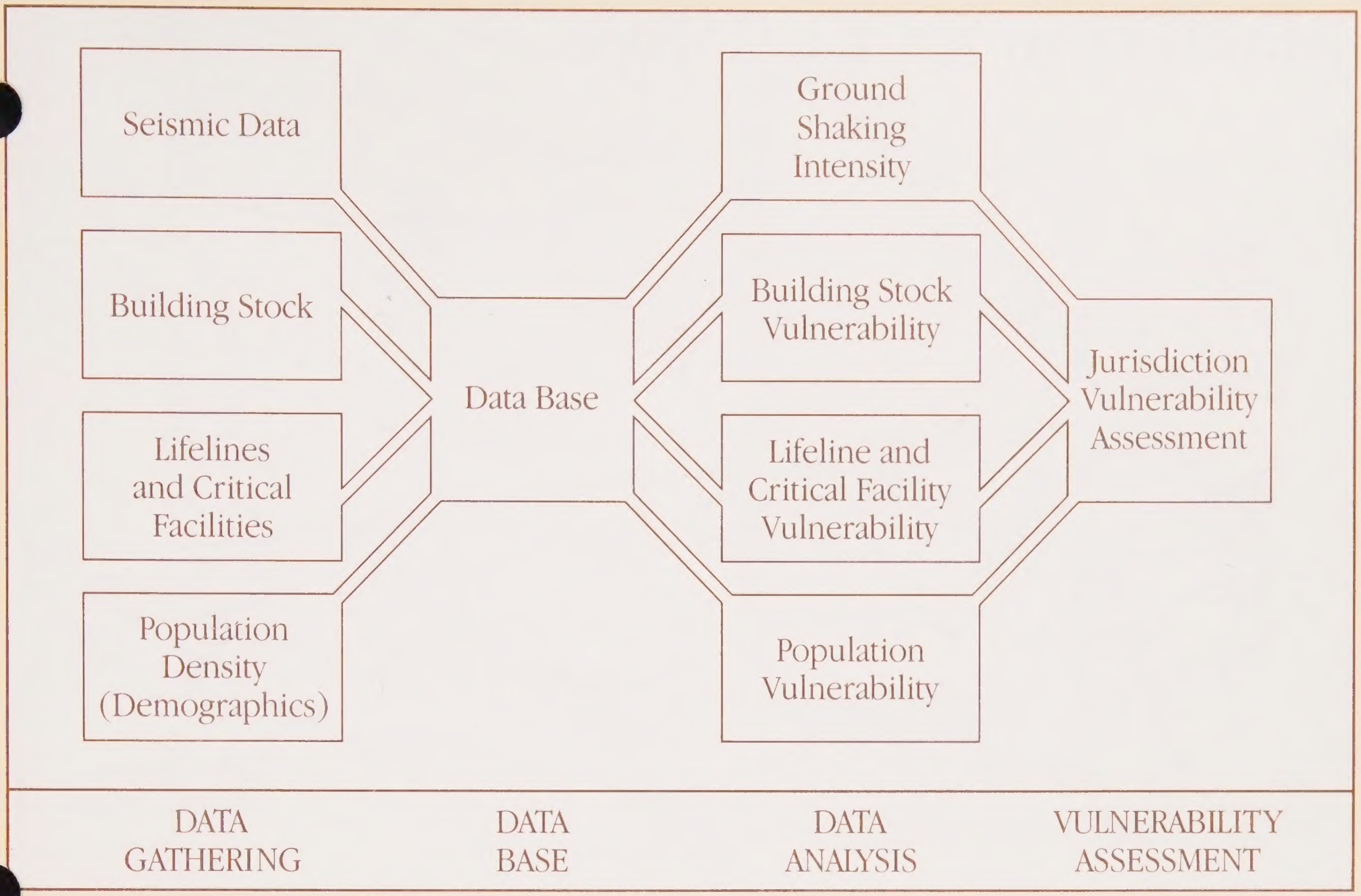
An earthquake vulnerability analysis paints a picture of what could happen to your community in a major earthquake. It gives information that decision makers and planners can use to estimate the jurisdiction's ability to respond to, and recover from, a large earthquake.

A vulnerability analysis can accomplish the following:

- Show the possible locations of, and damage to, major buildings and lifeline networks.
- Predict the general location, number, and types of structures which will be uninhabitable after an earthquake.
- Estimate the numbers and general locations of people likely to be killed, injured, or left homeless.
- Project post-earthquake reconstruction areas.

A vulnerability analysis can be used to:

- Gain fiscal and community support for actions needed to reduce vulnerability.
- Identify local code changes necessary to reduce the hazards of existing structures, and insure the safety of new ones.
- Guide decisions in the Emergency Operations Center during the response efforts that will follow an earthquake.
- Design disaster training and emergency preparedness exercises.

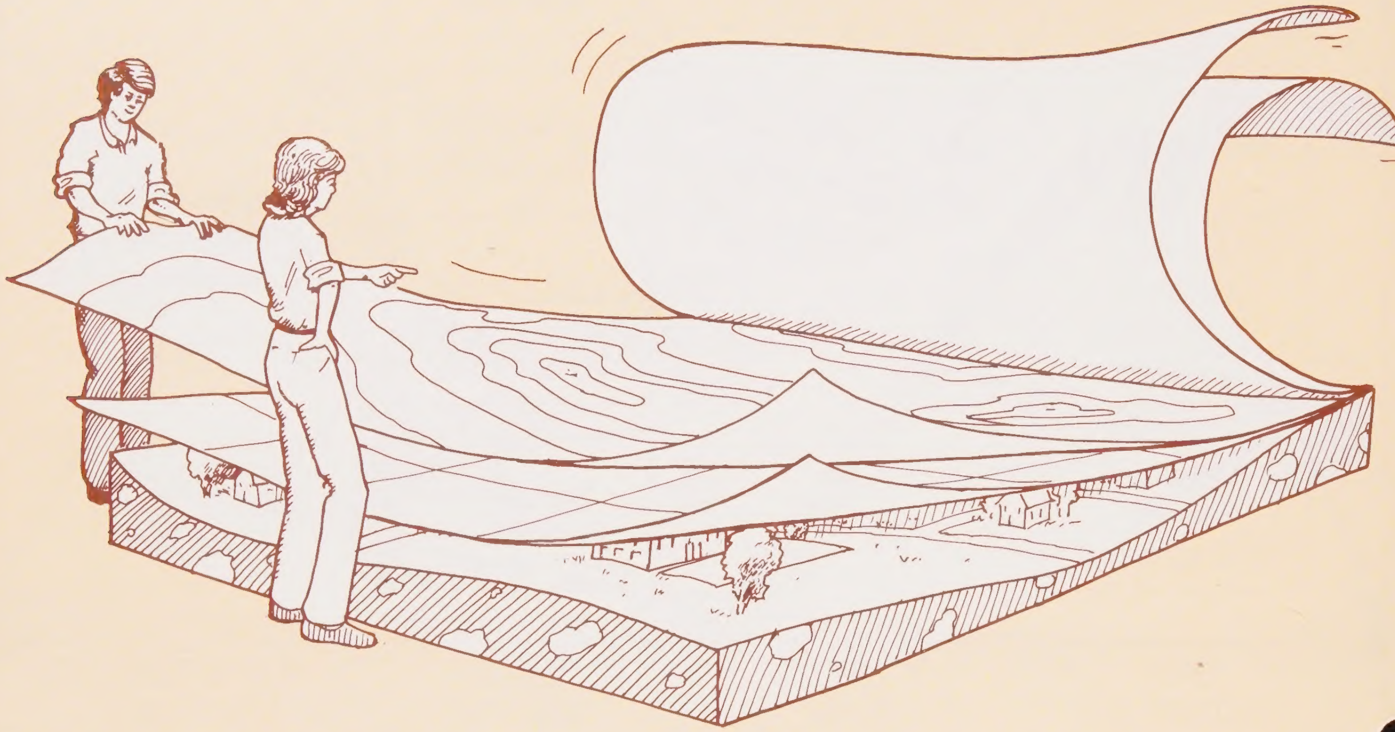


In short, an earthquake vulnerability analysis can point to potential trouble spots. It can help identify what can be done to improve public safety *before* an earthquake, and indicate where a community may need the most resources *after* an earthquake. It is a jurisdiction-specific analysis of potential problems, many of which can be solved.

An earthquake vulnerability analysis does not have to be done by outside specialists; a very effective analysis can be performed in most communities by existing personnel at minimal cost. Time is the primary investment required. Going through the process will substantially increase a jurisdiction's capacity to plan and prepare for a damaging earthquake.

The two major steps required for the development of an earthquake vulnerability analysis are: 1) developing base maps with data-specific overlays (a database); and 2) analyzing vulnerability using the information compiled in the database.

DEVELOPING YOUR DATABASE



Producing the Maps

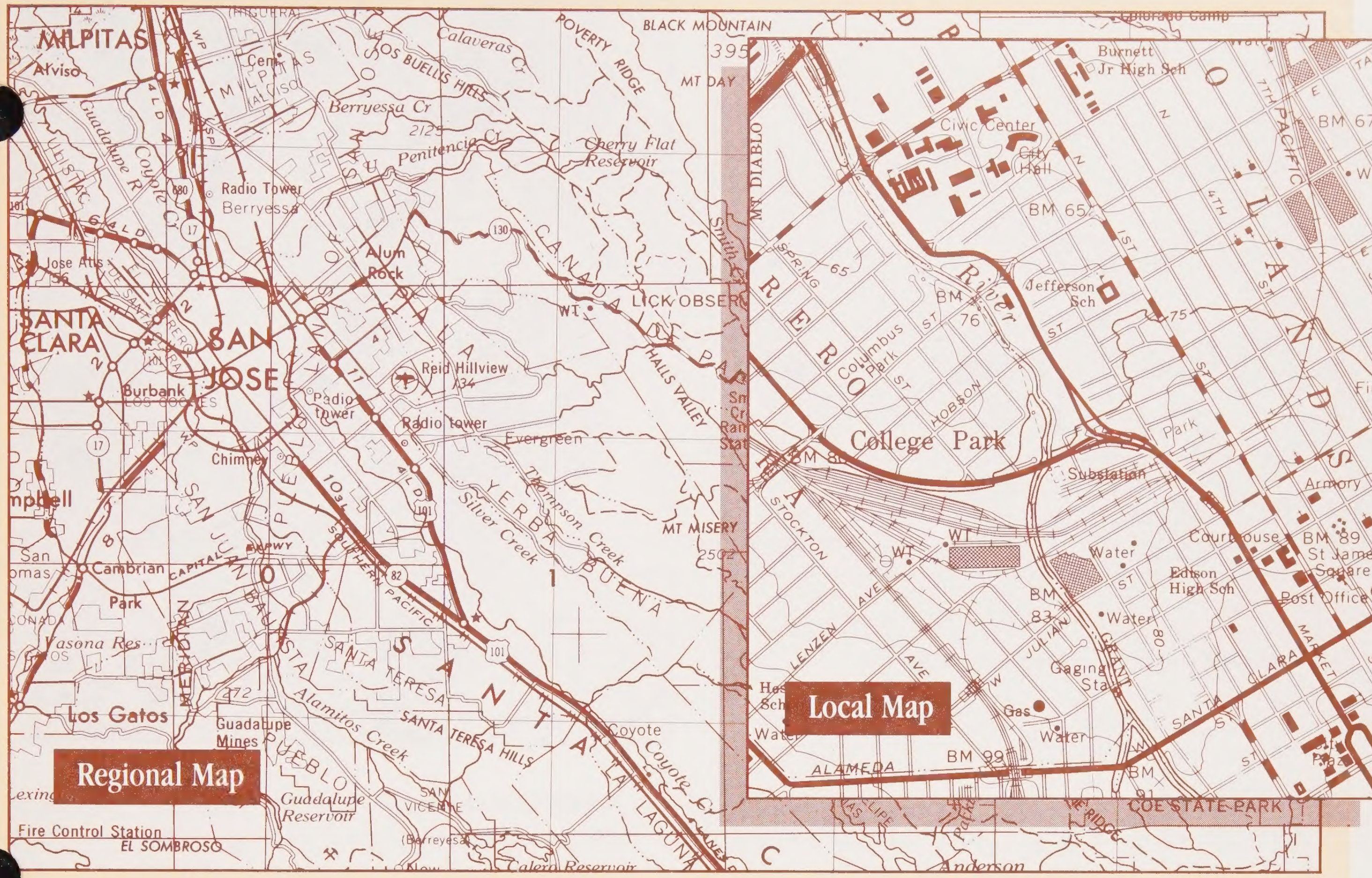
The database consists of local and regional base maps and a series of overlays. Constructing your database involves gathering regional and local base maps; plotting a geographic grid system for them; and developing several acetate overlays which show the locations of various seismically induced hazards, land uses, building stocks, lifeline networks, critical facility sites, and population concentrations.

Base Maps

Development of an accurate database starts with two base maps—one on a regional scale and the other on a local scale.

The ***regional map*** should include the area within a 25-mile radius of your jurisdiction. The regional map will be used for regional planning purposes, for example, to show the potential damage to regional transportation and other lifeline networks. A good scale for this map is 1:100,000 (1 inch = 1½ miles). The U.S. Geological Survey has regional topographic maps at this scale.

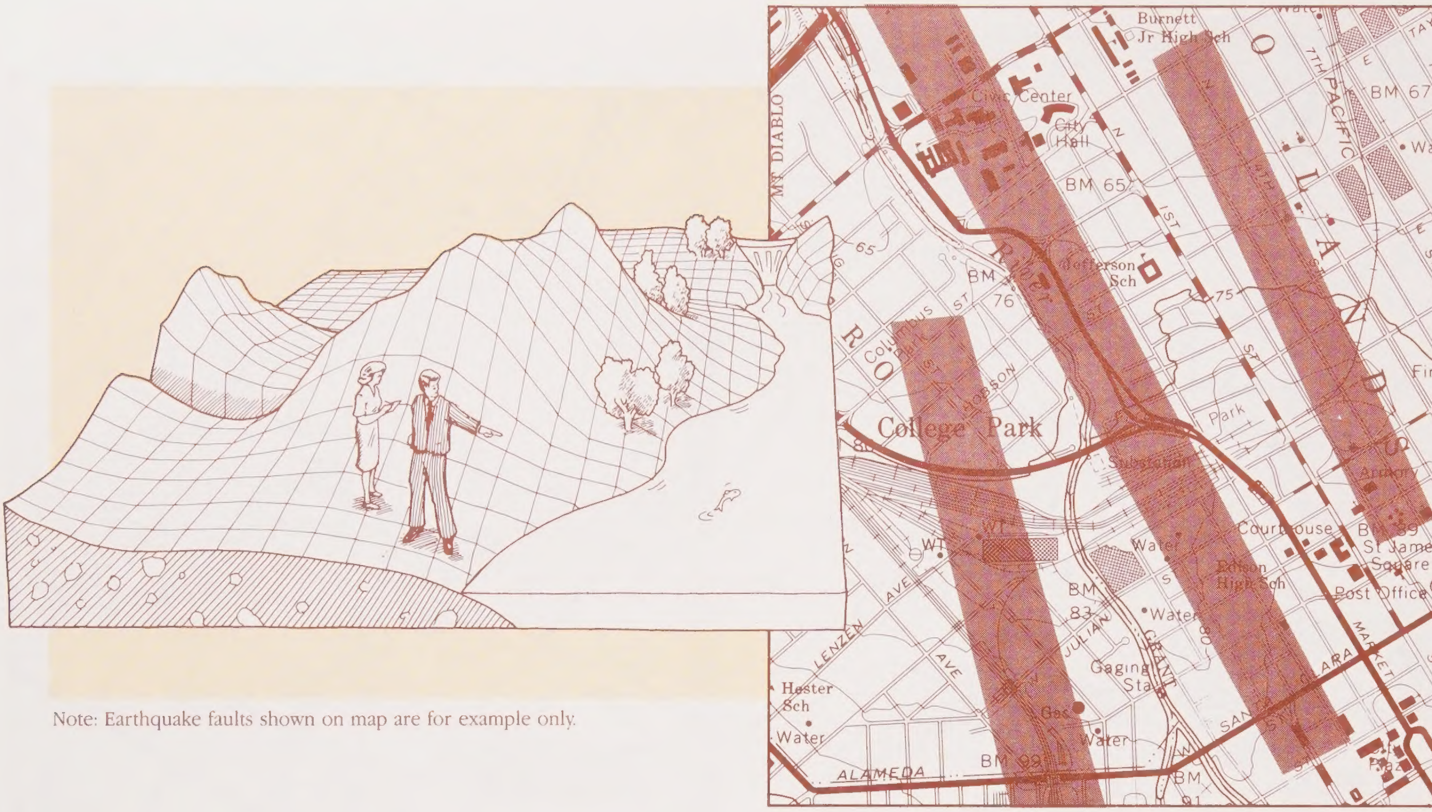
The ***local map*** should include only your jurisdiction and a mile or so beyond its boundaries. The local map will be used for identifying potential problems within the jurisdiction.



When selecting base maps, choose one that is familiar and understandable to all potential users. Most counties and many cities have a particular map they use for zoning and other planning or emergency response purposes; this would be a good one to use.

If a good local map is not available, use the U.S. Geological Survey (USGS) topographic maps (1:24,000 scale, 1 inch = 2000 feet) covering your jurisdiction, or check with either the California Division of Mines and Geology (CDMG) or the Association of Bay Area Governments (ABAG) (see **INFORMATION SOURCES** at the back of this publication). In addition, regional and local geologic maps from both the USGS and the CDMG are an excellent source of background information.

Once local and regional maps have been selected, a geographic grid reference overlay on clear acetate must be designed for both maps. Such an overlay is similar to the alpha-numeric locator system on published street maps. Whatever geo-referencing system is selected, it should be the same for both maps.



Note: Earthquake faults shown on map are for example only.

Map Overlays

Overlays on clear acetate should be developed for each base map. The maps and their overlays constitute your database.

For the ***regional map,*** the following overlays should be developed:

- Seismically induced hazards
- Lifeline networks
- Critical facilities (selected)

The ***local map*** should have the following overlays:

- Seismically induced hazards
- Building stock
- Lifeline networks
- Critical facilities
- Population locations

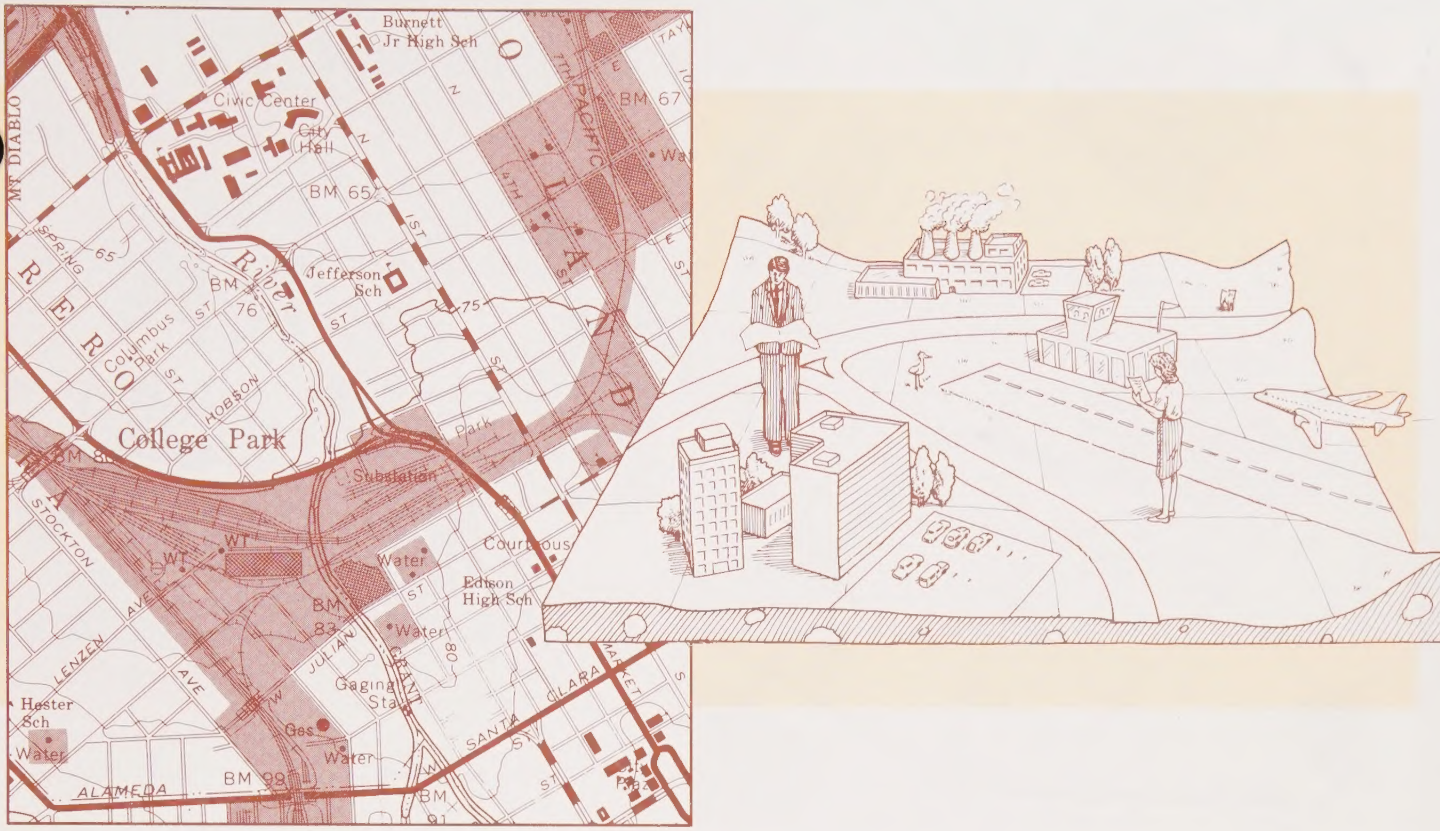
Taken together, these overlays provide a clear picture of the areas of the community at risk.

Seismically Induced Hazards Overlay. Proximity to faults and potential ground shaking are the two pieces of information necessary to estimate vulnerability. Obtain Special Studies Zones maps from the CDMG. These show the location of known active faults in the region, and are available in both regional and local scales. Plot all the active faults on an overlay for each base map.

Next, obtain seismic intensity (ground shaking) information from the CDMG. The CDMG issues *Special Publications* that show the expected ground shaking intensities along selected faults throughout the state; ABAG also has similar maps. Plot the data on ground shaking on the same overlay as the faults.

Most seismic intensity distribution maps are regional in scale, so plotting the data for the regional overlay is a simple task. However, transferring this information to a local map at a different scale is problematic. Define the boundaries between intensity zones broadly because the boundaries between shaking intensity zones are only best guess estimates.

Other information that should be plotted on the seismically induced hazards overlay includes liquefaction potential, and hill areas that are susceptible to landsliding in an earthquake. These data can be obtained from the USGS, CDMG, or ABAG.



Land Use Overlays. You need two overlays for land use information: one overlay for the buildings within the jurisdiction, and the other for lifelines and critical facilities. The building data should only be generated and plotted for use on the local map. The lifeline and critical facility data should be generated for local and regional maps.

The building stock of a jurisdiction can be divided into two categories: housing units, and commercial/industrial units. Show single family homes as well as apartment buildings, noting the number of units in each. Include mobile home parks if you have any. Plot the location of commercial or industrial structures within jurisdictional boundaries.

Three building types considered potentially hazardous in an earthquake are *unreinforced masonry* (URM), pre-1973 *nonductile concrete frame*, and *concrete tilt-up* construction. Each of these building types should be designated separately, since each poses different risks and problems. Use information on the location of URM buildings from the inventory required by SB547.

Lifelines and critical facilities can be plotted on the same overlay. Lifelines should be plotted on both the regional and local maps. Although critical facilities need only be plotted on the local map overlay, some jurisdictions may want to include certain critical facilities (for example, hospitals) on the regional map. The critical facilities that should be plotted on the local map include:

- Police and fire stations
- Hospitals (including convalescent hospitals)
- Dams, reservoirs, and pumping stations
- Radio towers
- Airports and helicopter landing areas
- Mass care centers
- Schools (public and private)
- Major supply warehouses (food, medical supplies)
- Toxic storage locations

The following lifeline networks should be plotted both regionally and locally:

- Major streets and highways
- Rail lines, stations, and yards
- Fuel pipelines and storage areas
- Natural gas lines
- High-voltage electrical lines
- Power plants and substations
- Communications facilities
- Sewer system and sewage treatment facilities
- Water storage facilities
- Water lines

Population Overlays. Two population overlays need to be developed for the local map: one to depict the daytime/at work population, the other to show the nighttime/weekend population.

The daytime population density figures show the location of people from 6 am to 6 pm, Monday through Friday. Be as specific as possible about the number of people in large public or commercial/industrial facilities.

The nighttime/weekend population overlay shows people at home, for the most part, and can be constructed using the most recent census information. The data should be aggregated and plotted at the census tract level (generally less than a square mile). Most public works or planning departments have census tract maps, or they can be obtained from the U.S. Census Bureau. This information can also be used to determine the location of groups in the population with special needs, such as the elderly or non-English speaking.

Results of Database Development

Completion of this first phase of an earthquake vulnerability analysis generates a pair of maps—one regional and the other local. The maps and overlays provide a picture of the areas of your community where there is earthquake damage potential.

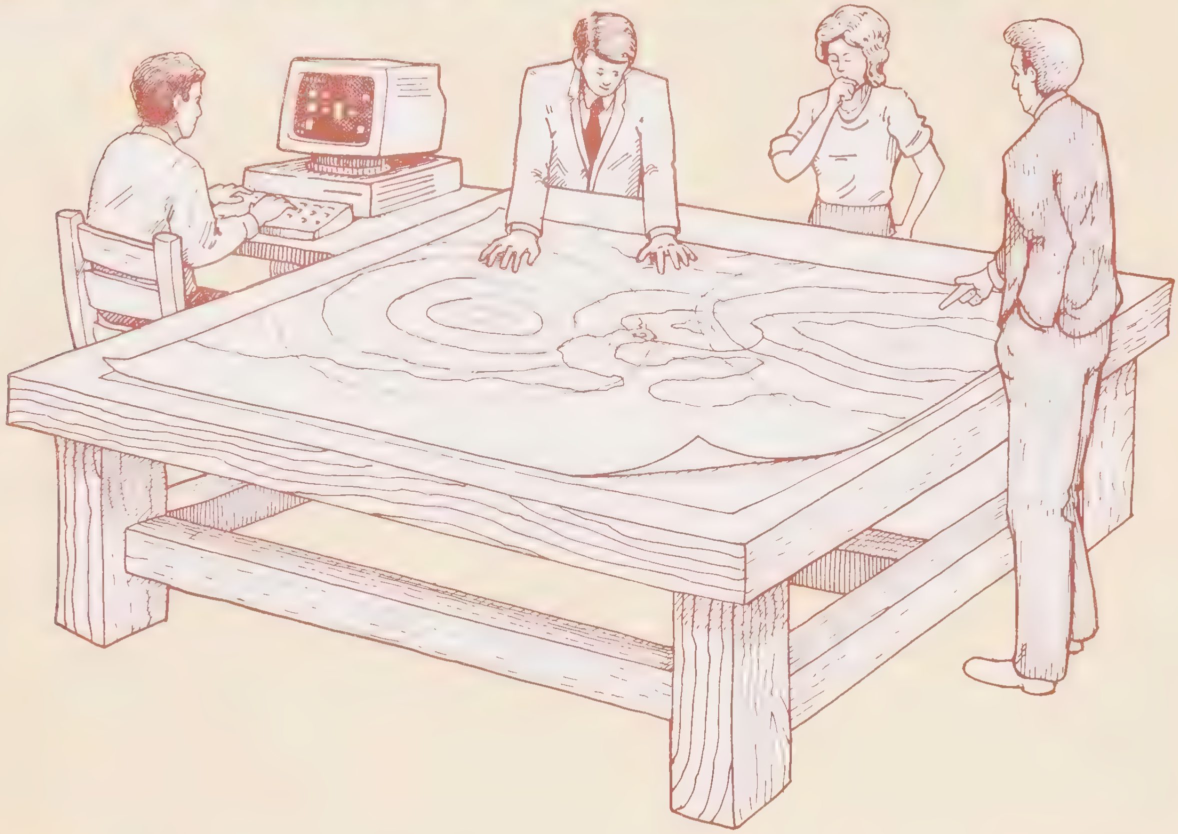
If the technical resources are available, computerization of the entire database is possible. The benefits of computerization are that data can be refined and continually updated. Computerization requires substantial monetary, hardware, software, and personnel resources not available in some communities. If your community is interested in pursuing computerization, contact the Association of Bay Area Governments in Oakland, California (see **INFORMATION SOURCES** at the back of this publication).

VULNERABILITY ANALYSIS CHECKLIST

ITEM	AVAILABLE LOCALLY?	DEPARTMENT	SOURCE
Regional Base Map	☐		USGS CDMG
Local Base Map	☐		USGS CDMG
♦ Special Studies Zones (local & regional)	☐		CDMG
♦ Seismic Intensity Information	☐		CDMG *Special Publications*
♦ Existing Land Use			
Local Building Stock	☑	♦ Assessor's Office ♦ Sanborn Maps ♦ URM Building Inventory	
Lifelines	☐		Utility Companies
♦ Population	☐		Census Bureau

Notes

ANALYZING EARTHQUAKE VULNERABILITY



The Steps

Vulnerability analysis involves 1) developing estimates of where damage is likely to infrastructure and buildings, and 2) determining which segments of the population are at greatest risk. Information compiled during database development is used to identify both high-priority responses and the steps necessary to reduce potential dangers.

Vulnerability analysis requires a multi-disciplinary approach, and should involve the expert judgment of local specialists (such as a geologist, seismologist, planner, engineer, and utilities expert). This process comprises three steps:

- *Seismic hazard analysis*—Understanding what is likely to happen to the earth during strong ground shaking helps to identify areas with the greatest potential for damage.
- *Building and population analyses*—Determining the effects of ground shaking on buildings, their contents (especially any hazardous materials), and the people who occupy them helps to indicate priorities for hazard reduction.
- *Lifeline network analysis*—Knowing the probable effects of ground shaking on utilities, roads, bridges, pipeline networks, and communication systems helps jurisdictions understand what problems they might have in a damaging earthquake and plan for contingencies.

Seismic Hazard Analysis

The information needed to accomplish this step is in your database. Ground shaking intensity maps were plotted as an overlay, although regional estimates of ground shaking and liquefaction potential are generalized to some degree and may not be detailed enough for block-by-block analysis within a jurisdiction. For planning purposes, existing data should be used and checked for accuracy by a geologist or seismologist familiar with the local geology. Most counties and cities have a geologist either on staff or on retainer who can perform this task. With these ground shaking data, estimates can be made about how various areas of the community may perform during an earthquake.

Building and Population Vulnerability Analyses

Although they are general in nature, the analysis methods described below will provide an estimate of potential building failures and are sufficient for general planning purposes.

The first step is to locate buildings in relation to strong ground motion. This is done by placing the building location overlay on top of the seismic intensity overlay. Buildings in each of the three classifications considered potentially hazardous (URM, pre-1973 nonductile concrete, and concrete tilt-up) will suffer varying levels of damage, depending on ground motion, potential for liquefaction, and the type of construction. Many of these damages can be estimated by the public works department for URM buildings. Damage estimates for other types of buildings will require more technical review by a structural engineer.

Once an estimate of structural damage has been made, it is possible to project both the potential number of uninhabitable structures after a quake, and the possible numbers of deaths and injuries. However, injuries and deaths also result from nonstructural causes (falling objects like bookcases and ceiling tiles). Because nonstructural hazards are very common in newer, seismically designed buildings as well as in older buildings, casualties will be difficult to project with great accuracy.

Estimates of the numbers of people left homeless because of damages to residences can be determined by multiplying the number of potentially uninhabitable homes by the average number of people in each residence. This number ranges between 2.5 and 3 people per unit, depending on the type of residence.

Lifeline Network Analysis

Lifeline network damage is best determined by using a team of professionals. The public works department, using ground shaking information, can estimate utility and lifeline network performance. Representatives of particular utilities and utilties specialists can provide useful information.

The lifeline network analysis is done by putting both the seismic intensity distribution overlay and the lifeline network overlay on the base map. Experts from the appropriate utility company can then assess the potential performance of the lifeline during a given amount of ground shaking.

The following information is needed for planning purposes:

- The location of damaged airports, rail lines, and traffic arterials.
- The location and percentage of service disruption for all utilities.
- Potential bridge, overpass, and main road closures.
- An estimate of the percentage of service that can be restored within 72 hours. Estimates for a return to near-normal service levels should also be made, and must consider the cumulative effects of all damaged lifelines and networks.

Data on regional lifeline networks in California Division of Mines and Geology *Special Publications* 60, 61, 78, and 90 serve as excellent background information for a more localized assessment.

SUMMARY

An earthquake vulnerability analysis should be part of every community's disaster planning effort. The database development and methods for vulnerability analysis outlined here will help a jurisdiction project and quantify the effects of a major earthquake. Preparedness, response, and recovery capabilities will all be increased in a community that does general planning, disaster planning, and consistent plan updates with information generated by vulnerability analysis.

The resources listed in the back of this guide can provide the information and materials needed to carry out your vulnerability analysis. They can also help you develop, update, or implement an earthquake preparedness plan. Additional information and assistance is available from the *Bay Area Regional Earthquake Preparedness Project, 101 8th Street, Suite 152, Oakland, CA 94607, (415) 540-2713.*

INFORMATION SOURCES

The following organizations are sources for publications and maps. Each of the organizations has many more resources than can be listed here, and catalogs should be obtained from most of them. It may be helpful to be included on their mailing lists in order to be apprised of new, useful information as it becomes available.

U.S. Geological Survey (USGS)

The USGS is the best source for a good base map in California. They carry maps in a variety of scales, both with and without topographic contours.

Maps are available *over the counter* at the following locations:

USGS
Customhouse, Room 504
555 Battery Street
San Francisco, CA 94111
(415) 556-5627

USGS
Building 3, Room 122
345 Middlefield Road
Menlo Park, CA 94025
(415) 883-8300

USGS
Federal Building, Room 7638
300 N. Los Angeles Street
Los Angeles, CA 90012
(213) 894-2850

Maps can be obtained *by mail* from:

USGS Map Distribution
Federal Center, Building 41
Box 25286
Denver, CO 80225

Topographic maps can also be obtained at many recreational supply stores.

California Division of Mines and Geology (CDMG)

Earthquake Planning Scenario for a Magnitude 8.3 Earthquake on the San Andreas Fault in Southern California. CDMG Special Publication 60. 1982.

Earthquake Planning Scenario for a Magnitude 8.3 Earthquake on the San Andreas Fault in the San Francisco Bay Area. CDMG Special Publication 61. 1982.

Earthquake Planning Scenario for a Magnitude 7.5 Earthquake on the Hayward Fault in the San Francisco Bay Area. CDMG Special Publication 78. 1987.

Earthquake Planning Scenario for a Major Earthquake on the Newport-Inglewood Fault Zone. CDMG Special Publication 99. 1988.

All of the above publications can be obtained from the following locations:

CDMG Publications
660 Bercut Drive
Sacramento, CA 95814
(916) 445-5716

CDMG
380 Civic Drive, Suite 100
Pleasant Hill, CA 94523
(415) 646-5920

CDMG
107 S. Broadway, Room 1065
Los Angeles, CA 90012
(213) 620-3560

Bay Area Regional Earthquake Preparedness Project (BAREPP)

101 8th Street, Suite 152
Oakland, CA 94607
(415) 540-2713

Comprehensive Earthquake Preparedness Planning Guidelines: County. Assist county governments in developing a comprehensive plan. Include functional areas and actions related to preparedness, mitigation, response, and recovery. References and a glossary. October 1985. 93 pages. (*See* SCEPP *below.*)

Comprehensive Earthquake Preparedness Planning Guidelines: City. Assist city governments in developing a comprehensive plan. Include functional areas and actions related to preparedness, mitigation, response, and recovery. References and a glossary. October 1985. 90 pages. (*See* SCEPP *below.*)

Hazardous Building Case Studies. A set of four, each describing a different building type: wood frame, tilt-up, unreinforced masonry, and concrete flat slab. For each type, the seismic retrofit of a representative building is described, and generic information is given on how the building type typically fails and can be strengthened. Includes photos, drawings, and a glossary. September 1988.

The Effective Use of Earth Science Information at the Local Government Level. Describes ways in which earth science information can and should be used in the planning process; identifies uses, users, and the effective presentation of data; and stresses communication among earth scientists and local government decision makers. June 1985. 16 pages.

Putting Seismic Safety Policies to Work. This guide was prepared to help communities take a fresh look at their seismic safety policies and decide how best to implement them. July 1988. 40 pages.

Southern California Earthquake Preparedness Project (SCEPP)

P.O. box 50310
Pasadena, CA 91115
(818) 795-9055

County and *City* guidelines similar to BAREPP's (above) are available from SCEPP.

Association of Bay Area Governments (ABAG)

P.O. Box 2050
Oakland, CA 94604-2050
(415) 464-7900

Regionwide Earthquake Hazard Maps. Twenty maps at 1:125,000 scale.

Using Earthquake Intensity and Related Damage to Estimate Maximum Earthquake Intensity and Cumulative Damage Potential from Earthquake Ground Shaking. Revised December 1983.

The San Francisco Bay Area—On Shaky Ground. Describes the ground shaking hazard in the San Francisco Bay Area and provides a dozen options for mitigating the hazard. Includes seven map sheets of the central San Francisco Bay Area including the cities of San Francisco, Oakland, Berkeley, and Hayward at a scale of 1:125,000 (1 inch = 2 miles). February 1987. 32 pages.

Building Stock and Earthquake Losses—The San Francisco Bay Area Example. Includes a classification of buildings, a discussion of building performance in earthquakes, analysis of several techniques for gathering building data, a description of building stock in the Bay Area, and a discussion of the uses of building data to define earthquake hazards and their mitigation. May 1986. 68 pages.

Building Stock Data. Actual building stock and land use data are available for each of the Bay Area's 1,200 census tracts. May 1986.

ABAG Census Data Bulletins and Area Profiles. Data from the 1980 Census Bureau (separate bibliography available). More info from (415) 464-7937.

Projections 87 by Census Tract. Population, income, age, employment, and land availability forecasts through the year 2005 for each of the Bay Area's 1,200 census tracts. August 1987.

Base maps with topo, highways, collector streets, BART, rail lines, electrical high voltage lines, aquaducts, drainage, and water bodies for the cities and nine counties of the Bay Area. Scale 1:125,000 (1 inch = approx. 2 miles).

The Liability of Local Governments for Earthquake Hazards and Losses: A Guide to the Law and its Impacts in the States of Alaska, California, Utah and Washington. Includes discussions on rules governing the legal liability of local governments for earthquake hazards and losses, the effect of liability rules on earthquake safety mitigation programs, several hypothetical situations, and approaches for using liability to promote safety. February 1989. 52 pages.

Southern California Association of Governments (SCAG)

818 West 7th, Suite 1200
Los Angeles, CA 90017
(213) 236-1300

Some publications similar to ABAG's, above.

U.S. Census Bureau

1417 Clay Street
San Francisco, CA
(415) 273-6210
or
11777 San Vincente Blvd.
Los Angeles, CA
(213) 209-6612

Federal Emergency Management Agency (FEMA)

Single copies of the numbered documents can be obtained at no cost. "In Press" documents will be available before the end of 1989 from:

FEMA
P.O. Box 70274
Washington, DC 20024

Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook. FEMA Publication #154 (Earthquake Hazard Reduction Series 41). 1988.

Rapid Visual Screening of Buildings for Potential Seismic Hazards: Supporting Documentation. FEMA Publication #155 (Earthquake Hazard Reduction Series 42). 1988.

Typical Costs for Seismic Rehabilitation of Existing Buildings: Summary. FEMA Publication #156 (Earthquake Hazard Reduction Series 39). 1988.

Typical Costs for Seismic Rehabilitation of Existing Buildings: Supporting Documentation. FEMA Publication #157 (Earthquake Hazard Reduction Series 40). 1988.

Established Programs and Priorities for the Seismic Rehabilitation of Buildings: A Handbook. Building Systems Development, Inc. 1989 (In Press).

Established Programs and Priorities for the Seismic Rehabilitation of Buildings: Supporting Report. Building Systems Development, Inc. 1989 (In Press).

Detailed Seismic Evaluation of Existing Buildings: A Handbook. Applied Technology Council. 1989 (In Press).

Detailed Seismic Evaluation of Existing Buildings: Supporting Documentation. Applied Technology Council. 1989 (In Press).

Techniques for Seismically Rehabilitating Existing Buildings. URS/John Blume and Associates, Engineers. 1989 (In Press).

Single copies of the following publication are available from:

National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, DC 20418

Estimating Losses from Future Earthquakes. National Research Council Committee on Earthquake Engineering, National Academy Press, 1989.

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